concluded either that the diffuse sky radiation at a given place is extremely important (ratio of vertical component of solar radiation to that from sun plus sky was in Washington 0.80, in Davos 0.92) or that the difference lies in instrumental errors, of which a clue might be found in the above-mentioned investigation by Eric R. Miller of the Callendar recorder.

A comparison between the curves of heat radiation and the brightness curves given in the January, 1921, issue of the *Meteorologische Zeitschrift* shows, as one might expect, that the former has a smaller amplitude than the latter. As a rough approximation, to illustrate, the brightness intensity increases in the ratio 1:1.5:2 with solar altitudes of 15, 20, and 25°, while the heat radiation increases in the ratio 1:1.35:1.5. This point will be discussed later.

In spite of the three small residual errors discussed above, the instrument has proved itself to be a great advance and will probably gain general use. It will serve a useful purpose in many investigations which are of great importance to meteorological advances and which depend upon the interchange of heat between the earth, sun, atmosphere, and space. This will depend also upon a correct understanding of the relations of nocturnal radiation to temperature and humidity and to the type and amount of clouds. Furthermore, the instrument will serve to give the values of "vorderlicht" and "unterlicht" (vertical surface, and horizontal surface exposed downward) in calorie measurements; it will give data on the relations between altitude and optical purity and radiation; and if a suitable bell-glass is perfected it will extend investigations on single parts of the spectrum. The results obtained with this instrument may also be a valuable check on the results obtained with other differently constructed instruments; in order that we may be sure of an experimental result, it seems important that it should appear on the basis of different methods agreeing with one another.

NOCTURNAL TEMPERATURE INVERSIONS IN OREGON AND CALIFORNIA.

551.574:634.1 (794)(795)

By FLOYD D. YOUNG, Meteorologist.

[Weather Bureau Office, Portland, Oreg., Jan. 5, 1921.]

SYNOPSIS.

Not enough attention has been paid in the past to locating crops subject to damage by frost on the more frost-free hillsides; and at the present day the phenomenon of nocturnal temperature inversion is not well understood by most fruit growers. Orchards set out 20 years ago in some of the coldest sections in several fruit districts on the Pacific coast are still being operated at a loss, while others have been removed only during the last two or three years. Detailed records of nocturnal temperature differences on slopes, covering entire frost seasons, are scarce.

Observations of nocturnal temperature inversions, made at Pomona, Calif., and Medford, Oreg., during the frost seasons of 1918, 1919, and 1920, are given in detail and discussed in this paper. Inversions at Pomona during the winter are compared with those at Medford during the spring. Differences in minimum temperature as great as 28° F. were observed between stations at the base and 225 feet above the base, on a hillside at Pomona.

The greatest inversions occur on clear, calm nights, following warm days. The duration of the minimum temperature on the hillside is usually much shorter than on the valley floor below, on account of large fluctuations in temperature during the night on the hillside.

On every hill where observations were made, the data indicate that on clear, calm nights the top of the hill is colder than points on the hillside some distance below.

The temporary vertical distribution of temperature found in the atmosphere over a plain or a valley floor on clear, calm nights, wherein the air temperature increases from the ground up to a height of from 100 to 1,500 feet above the ground, is called "nocturnal temperature inversion."

The steps in the development of a nocturnal temperature inversion may be summarized briefly as follows:

During a clear, calm day the temperature of the ground surface is raised through heat received by radiation from the sun, and the air in contact with the ground is warmed by conduction. This warmed air is forced upward and replaced by cooler and denser air from near by or above, and a circulation is established, which continues as long as the ground surface is warmer than the air in contact with it. Near sunset the air up to a height of a thousand feet or more is very nearly in adiabatic equilibrium.

After the sun goes down, the surface of the ground loses heat rapidly by radiation to the sky and its temperature soon falls below that of the air in contact with it. The surface air cools through conduction of heat into the colder ground, and its density becomes increasingly greater. Its increased density tends to keep it in contact with the ground, where it continues to grow colder and colder throughout the night. As air is a poor conductor and radiator of heat, the temperature of the air a few hundred feet above the ground falls much more slowly, and by sunrise a considerable difference in temperature has developed between the air at the surface of the ground and that a few hundred feet above the ground.

In the case of a valley, with fairly steep slopes on either side, the minimum temperature on a frosty night is likely to be much lower on the valley floor than at points on the hillside, the highest minimum temperature occurring at a height of from 200 to 1,500 feet above the valley floor.

A knowledge of the average and extreme differences in temperature between different portions of the hillsides and the valley floor is of great practical value in deciding where certain crops will be grown. If this information is available, crops most susceptible to damage by frost can be planted at the level on the hillside where the highest minimum temperature is found most frequently, and the colder locations on the floor of the valley can be utilized to grow more frost-resistant crops.

A single season's observations may be misleading, as the nocturnal temperature inversion varies from year to year in the same way that one season's weather differs from another's. At long intervals "freezes" are likely to occur, in which low temperatures are accompanied by high winds, and crops on the hillsides suffer as much, or even more, damage than those on the valley floor.

Temperature inversion [1] also plays an important part in the protection of crops by orchard heating; the extent of the inversion and the amount of wind largely determine what the efficiency of the heaters will be on a given night. A strong wind will prevent the development of a marked temperature inversion by keeping the air at different levels thoroughly mixed; in localities where low temperatures during the growing season usually occur with little air movement, orchard heating can be practiced with greater success than in districts where low temperatures are often accompanied by high winds.

In most of the orchard districts in the Pacific coast States, either through lack of knowledge or through dis-

[1] See Humphreys, W. J.: Frost Protection. MO. WEATHER REV., October, 1914, 42: 562-564.

regard of the facts regarding temperature differences between hillside and valley floor, orchards were planted in some of the coldest locations in each section. These were generally brought into bearing at considerable expense before the discovery was made that low temperatures caused the loss of the greater portion of the crop nearly every year. In many cases these orchards have been cared for year after year, passing from hand to hand as each new owner, in turn, discovered that they could not be operated except at a loss. Most of them are now in the process of removal, but they have left a large number of people richer in experience and poorer in material resources.

Of course, this applies only to orchards in the most unfavorable locations; in many cases orchards on the valley floors have been operated with marked success, damage by frost either being prevented by artificial means, or the amount of loss in the long run not being great enough to make the business unprofitable.

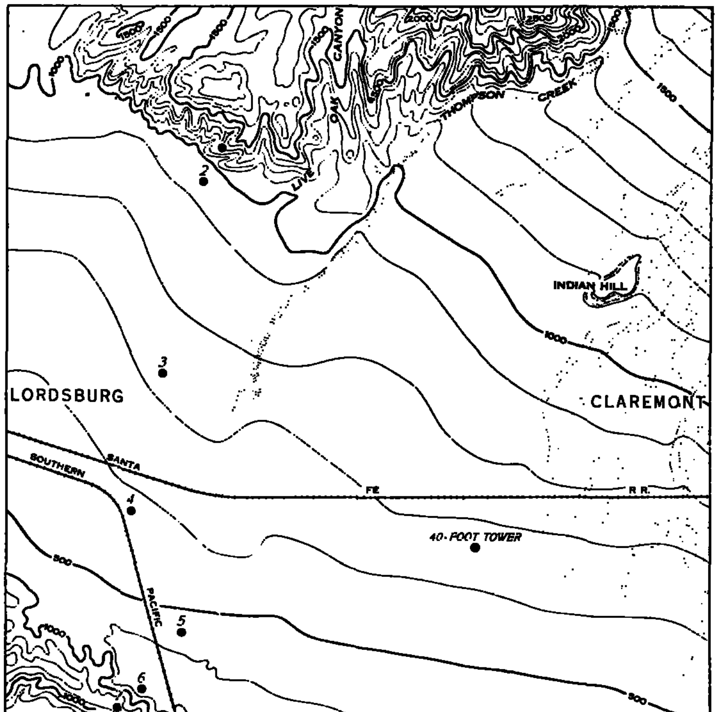

FIG. 1.—Topographic map of the Pomona Valley, Calif., showing locations of temperature survey stations and instrument tower. Contour interval 50 feet.

Factors other than the relative amount of loss through damage by frost, such as availability of water for irrigation, the character of the soil, difficulties in cultivating and irrigating steep slopes, must be taken into consideration in selecting a location for an orchard; if all available slopes in the fruit districts were set to orchards and all the orchards on the lowlands were removed, the acreage in fruit would probably fall far short of the present mark. There also seems to be considerable basis for the contention that citrus fruit grown in districts where frosts seldom occur is of a poorer quality than that grown where temperatures near the limit of endurance for the variety are of frequent occurence during the winter.

HILLSIDE AND VALLEY TEMPERATURES AT POMONA, CALIF.

During the winter of 1917–18 temperature survey stations were established in a line across the northern half of the Pomona Valley, in Southern California, for the purpose of obtaining information regarding local temperature inversions. The locations of these stations are shown in figure 1. (See also figure 2.) Maximum and minimum thermometers were exposed at each station in fruit region instrument shelters,[2] the instruments at all stations being about 4½ feet above the ground. A seven-day thermograph was operated at station 1, and 29-hour thermographs at stations 7, 8 and 9. Thermometers were read daily except at station 1, which was visited at least once each week, and oftener when practicable.

Minimum temperatures at stations 1, 2, 7, 8, and 9, for the 29 clear nights of the frost season of 1917–18 are given in table 1. A profile of the valley, showing the locations of the stations and the average minimum temperature at each, is shown in the MONTHLY WEATHER REVIEW [3] for August, 1920. The greatest differences in minimum temperature during the period from January 6 to February 16, 1918, were 22.0° F. on February 4 between stations 1 and 2 (170 feet), 21.8° F. on February 10 between stations 8 and 9 (125 feet), and 21.9° F. on February 10 between stations 7 and 9 (250 feet). On January 1, 1918, before station 1 had been established, the minimum temperature at station 7 was 24.0° F. higher than the minimum at station 9.

During the 1918–19 frost season stations were established at intervals of 50 feet vertical elevation, from the summit of San Jose Hill (station 7, figure 1) down to an elevation of 125 feet above the base station. (See figure 2.) From this point to the base stations were established for every 25 feet vertical elevation. A profile of this hillside, showing the location of each station, with the average minimum temperatures for the 45 clear nights of the season, and the actual minimum temperatures recorded on the night of January 5–6, 1919, is shown in the MONTHLY WEATHER REVIEW [3] for August, 1920.

Daily minimum temperatures at all stations on this hillside for all clear nights during the 1918–19 frost season are given in Table 2.

The greatest difference in minimum temperature between the base and 275-foot stations was 25.7° F. on January 8, while the greatest difference between the base and 225-foot stations was 28.0° F. on January 6. The minimum temperature at the summit was higher than the minimum at the 225-foot station on only one clear night during the season; and on that date it was only 0.1° F. higher. The average minimum temperature for all clear nights during the season was 1.6° F. higher at the 225-foot station than at the summit, and the average minimum temperature 150 feet below the summit was higher than at the summit.

[2] For a description of this shelter see the MO. WEATHER REV., December, 1920, 48: 709–710.

[3] Young, F. D.: Effect of topography on temperature distribution in Southern California. MO. WEATHER REV., August, 1920; 48: 462.

As the minimum temperature was practically never reached at all stations simultaneously, the inversion at a given hour during the night was often greater or less than the difference between the minimum temperatures.

Enlarged and corrected thermograms from stations at the base and on the slope of San Jose Hill, for two nights, with large and slight temperature inversions, respectively, are shown in figures 3 and 4. It will be noted that the fall in temperature at the lower stations is fairly steady, while there are large fluctuations in temperature at the stations on the slope. Because of these rapid changes, which occurred at the higher stations on every clear night, the duration of the minimum temperature was usually much longer at the base stations than at those on the slope. The minimum temperatures alone, therefore, do not indicate the amount of damage sustained by crops at different elevations on a given night.

Blair [4] noted similar fluctuations in temperature during the night at stations on the slope of Mount Weather.

[4] Blair, W. R.: Five-year summary of free air data; *Bull. Mt. Weather Observatory*, 1913; 6: 122–123.

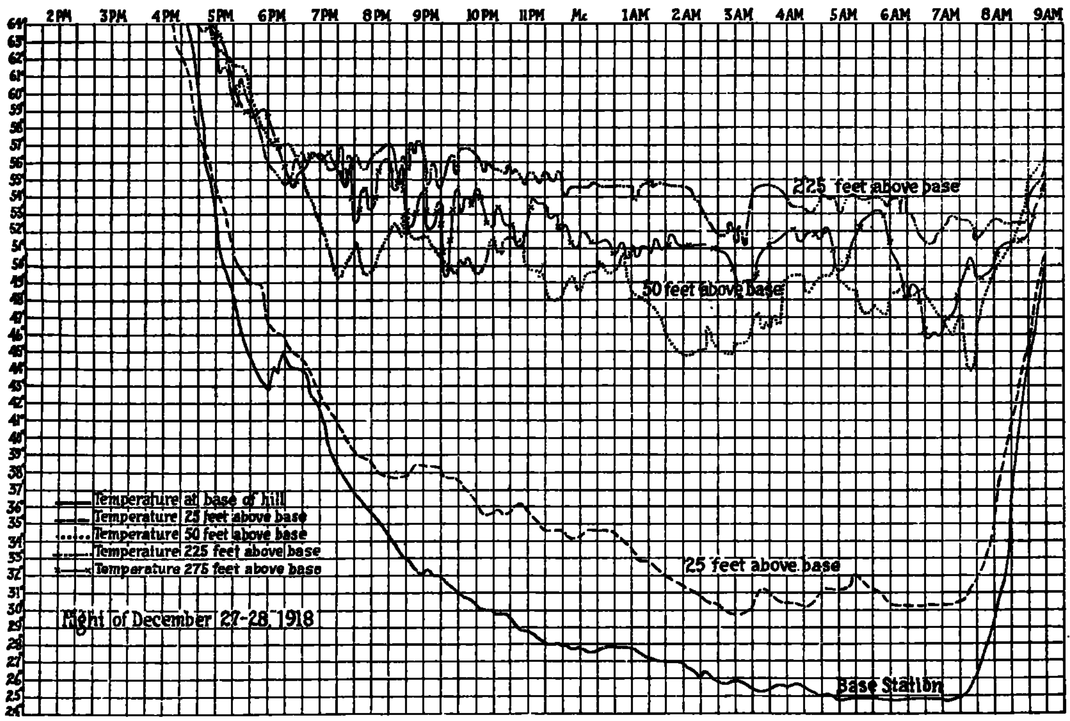

FIG. 3.—Corrected thermograms from stations at the base, and 25, 50, 225, and 275 feet above the base of the south slope of San Jose Hill (see fig. 1) on a night with large temperature inversion. A view of the slope on which these records were obtained is shown in fig. 2.

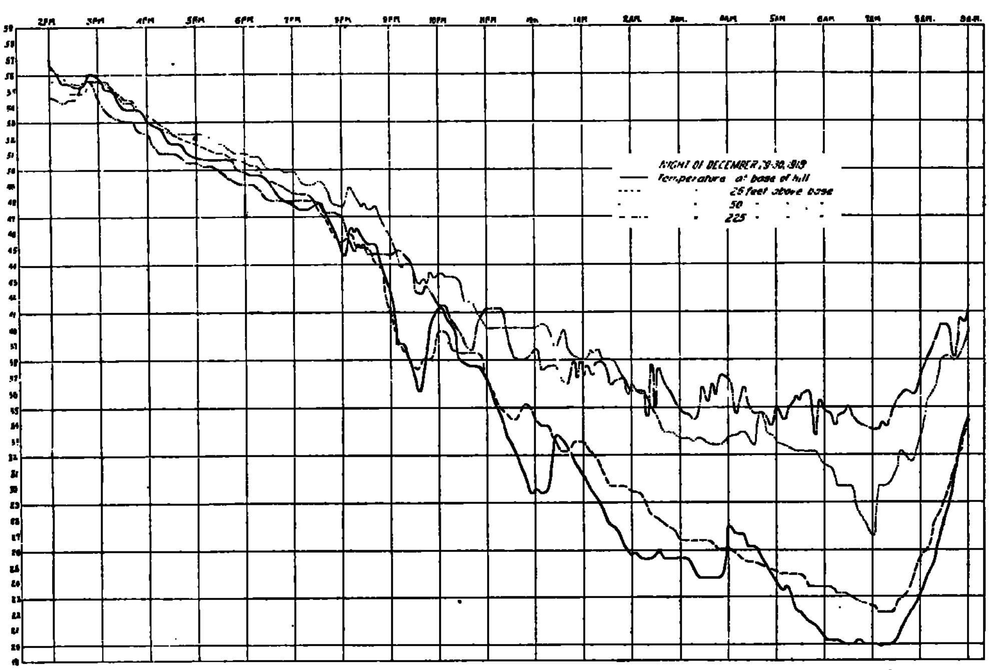

FIG. 4.—Corrected thermograms from stations at the base, and 25, 50, and 225 feet above the base, of the south slope of San Jose Hill (see fig. 1) on a night with slight temperature inversion. A view of the slope on which these records were obtained is shown in fig. 2.

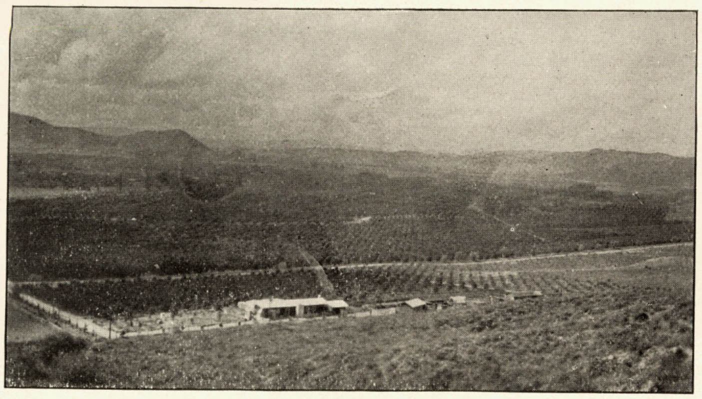

Fig. 2.—View of the Pomona Valley, looking southward from station 7. Station 8 is located near the house shown in the center of the picture. Station 9 is located at the base of the hill, near the left of the picture. (See fig. 1.)

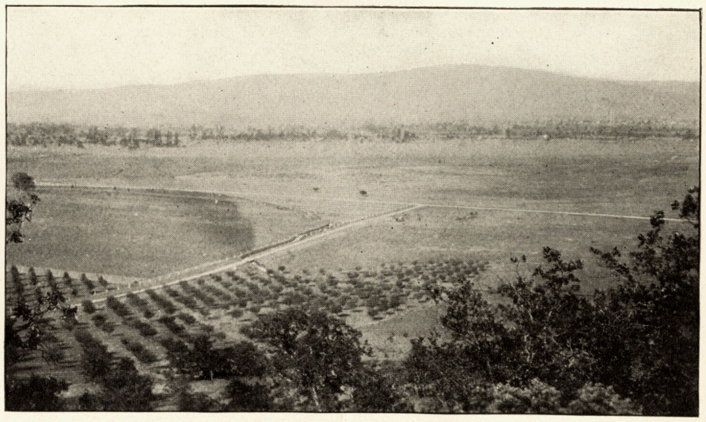

Fig. 7.—View from Coker Butte (station 1, fig. 9), looking westward across the valley. The wireless towers can be seen in the background at the right. Stations 6, 7, and 8 (fig. 9) lie in a straight line beyond the wireless towers.

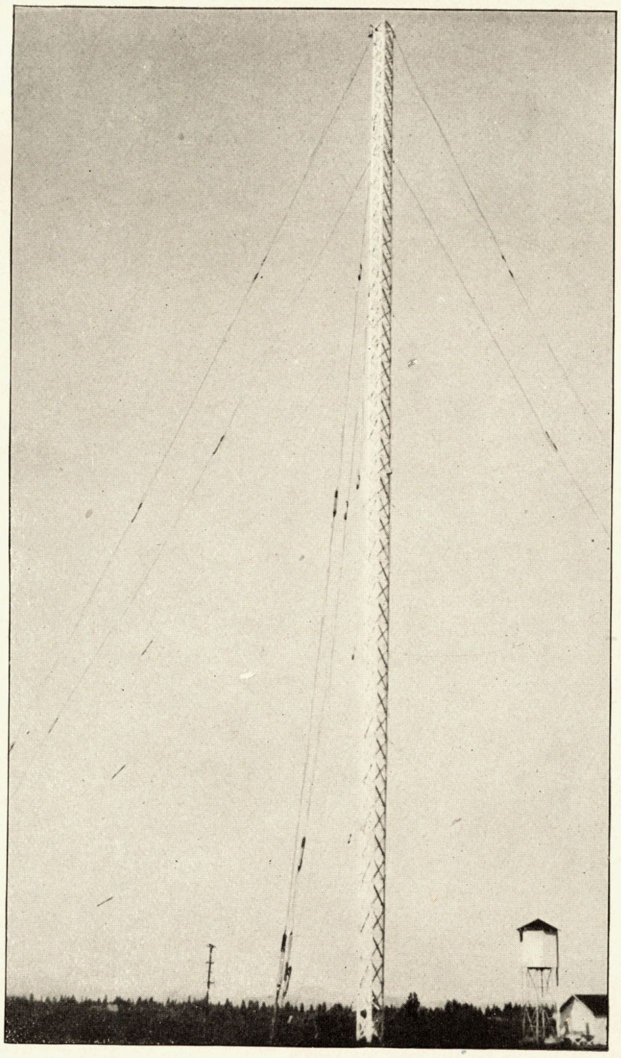

Fig. 8.—Three hundred-foot wireless tower, near Medford, Oreg., used in making temperature inversion studies (see fig. 9). Photograph by J. Cecil Alter.

From an examination of table 2, it will be noted that the greater part of the inversion is in the first 50 feet above the base of the hill; on most nights there was a difference of only a few degrees between the minimum temperatures at the 50-foot and 225-foot stations. These and other observations show that on clear, calm nights an extremely thin stratum of cold air covers the entire valley floor, with much warmer air only 50 to 100 feet above.

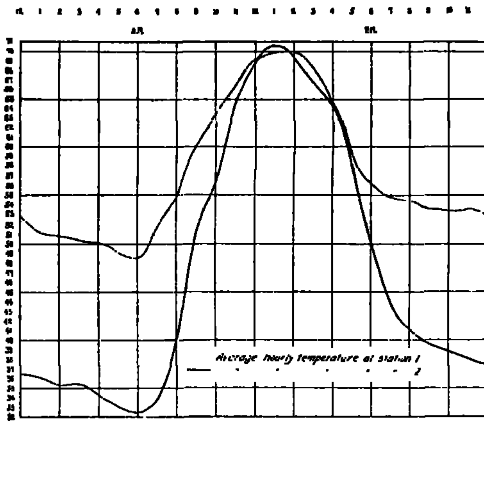

FIG. 5.—Average diurnal variation in temperature at stations 1 and 2 (fig. 1) for 12 clear days during January and February, 1918.

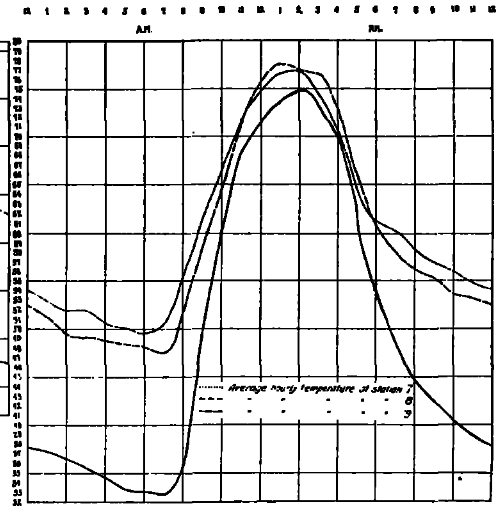

FIG. 6.—Average diurnal variation in temperature at stations 7, 8, and 9 (see fig. 1), for 21 clear days during January and February, 1918.

This sharp inversion of temperature is probably due to abnormally low valley temperatures. Thermograms from the hillside stations do not show the lower maxima usually found at hillside stations. The average maximum temperature for 21 clear days during the months of December, 1917, January and February, 1918, is 3° F. higher at station 8 and 2° F. higher at station 7, than the average maximum for the same dates at station 9, 250 feet below the summit. The average diurnal variation in temperature at hill and valley stations during 1918 is shown in figures 5 and 6.

The humidity is generally low in the Pomona Valley, often extremely so when the wind is blowing from the east or northeast. Relative humidities as low as 5 per cent and dewpoints as low as 3° F. have been indicated by carefully made sling psychrometer readings. With little moisture in the air to retard nocturnal radiation, the temperature in the valley falls rapidly after the sun goes down. The closely planted citrus trees, with their heavy foliage, offer considerable obstruction to surface air movement and probably are also somewhat effective in lowering the maximum temperature within the orchards through evaporation from the leaf surfaces. The dark foliage probably radiates heat during the night at a more rapid rate than would the lighter-colored ground, with no covering.

HILLSIDE AND VALLEY TEMPERATURES AT MEDFORD, OREG.

Observations of nocturnal differences in temperature between stations at the bases and on the slopes of hills in the Rogue River Valley were carried on during the spring frost seasons of 1918 and 1919. During the 1918 season stations were established in a line across the valley, from the summit of Coker Butte (elevation, 1,650 feet) on the east (see fig. 7), to a point on the foothills on the west side of the valley (elevation 1,450 feet). About half the distance between the base stations on either side instruments were exposed at the base and at elevations of 150 feet and 300 feet above the ground on a 300-foot wireless tower,[5] (see fig. 8), to measure the temperature inversion in the free air directly above the valley floor. The locations of all these stations are shown in figure 9.

Minimum temperatures observed on clear nights during the spring frost season are given in Table 3. The average minimum temperatures for the season are entered at each station in figure 9.

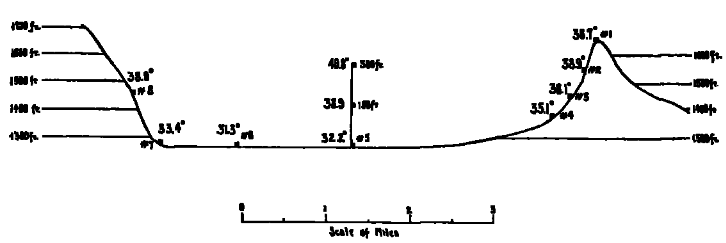

FIG. 9.—Profile of valley near Medford, Oreg., showing locations of temperature survey stations (see figs. 7 and 8). Elevations in feet above mean sea level.

The steepness of the nocturnal temperature gradient was slightly greater on the wireless tower than on the hillsides on either side of the valley, probably because the free air gradients were more nearly approximated on the tower.

At Coker Butte, on the east side of the valley, the highest minimum temperatures were recorded at station 2, 100 feet below the summit, and at station 3, 200 feet below the summit, the average minimum temperature was only 0.6° F. less than at station 1, on the summit.

Minimum temperatures at stations 8 and 3, at the same elevations but on opposite sides of the valley, were generally very nearly the same, but the minimum at the 150-foot station on the wireless tower, 40 feet lower, averaged 1 degree higher. Minimum temperatures at the 300-foot station on the wireless tower averaged 1.9° F. higher than those at station 2, on the slope of Coker Butte and at practically the same altitude.

At the wireless tower the inversion was generally nearly all in the lower 150 feet. The temperature was usually higher at the base than at the 150-foot level until 6 p. m., or even later. Between 7 p. m. and 11 p. m. the tem-

[5] The first temperature observations on this tower were made in 1916 by J. Cecil Alter.

perature at the base fell rapidly, developing a steep gradient between the base and 150-foot stations. From this time until sunrise the temperature at the ground fell more slowly and there was no increase in the steepness of the gradient; in fact, the thickness of the layer of cold air often increased sufficiently between 11 p. m. and midnight to cause a rapid fall in temperature at the 150-foot station, reducing the steepness of the gradient in the lower air. Temporary rises in temperature often occurred at one level and not at the other, sometimes reversing the gradient between the 150-foot and 300-foot stations.

On the western side of the valley nocturnal temperature gradients were not so steep as at the location of the wireless tower, although the hourly gradients on nights with large inversions show the same general characteristics. The greatest inversion generally occurred between 9 p. m. and 11 p. m., and there was often a decrease in the steepness of the gradient after this time.

The average diurnal variation in temperature at stations 1, 5, 7, and 8, and at the 150-foot and 300-foot stations on the wireless tower (see fig. 9), for 24 days during April and May, 1918, is shown in figures 10, 11, and 12. The difference between free air temperatures over the valley floor (shown by the records obtained at the wireless tower) and those on the hillsides is shown graphically. On the east side of the valley the afternoon temperature is higher at the summit than at the valley station, while at the wireless tower the temperature is lower at the 300-foot station than at the base by almost double the adiabatic rate, from 8 a. m. until noon, the period when convection is most active.

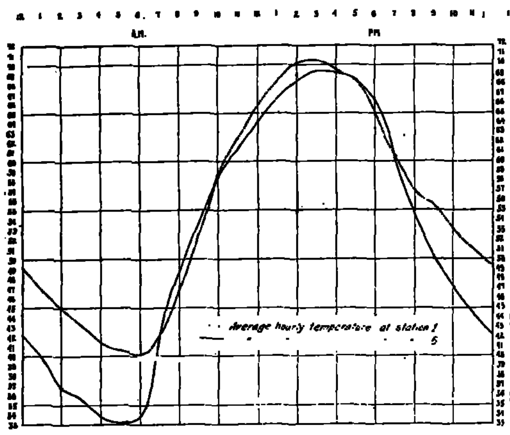

FIG. 10.—Average diurnal variation in temperature at stations 1 and 5 (fig. 9) for 24 clear days during April and May, 1918.

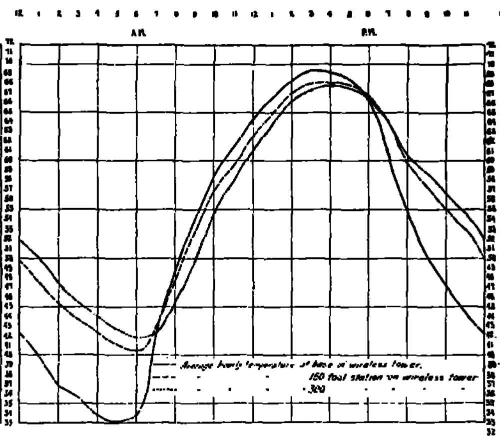

FIG. 11.—Average diurnal variation in temperature at stations at the base, and the 150-foot and 300-foot stations on wireless tower (see figs. 8 and 9) for 24 clear days during April and May, 1918.

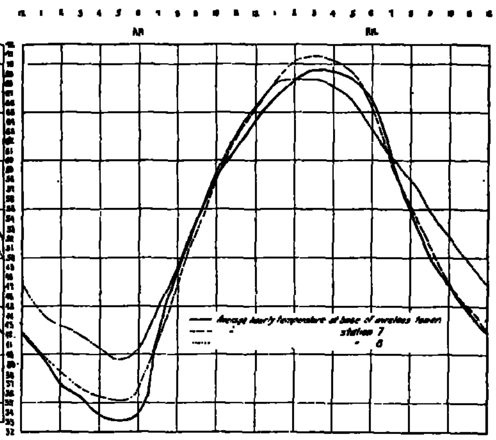

FIG. 12.—Average diurnal variation in temperature at stations 5, 7, and 8 (fig. 9) for 24 clear days during April and May, 1918.

The temperature at the base of the tower falls below the temperature at both the upper stations about 6 p. m., and the temperature at the 150-foot level falls below the temperature at the 300-foot level about 7 p. m.

On the west side of the valley the temperature at station 8 falls below that at both stations 6 and 7 about 1.30 p. m., and the temperature at the two lower stations does not fall below that at station 8 again until about 7 p. m. This is probably due to the fact that the sun's rays are almost parallel to the slope during the early part of the afternoon and that later the whole upper slope is shaded from the sun some time before insolation is cut off from the valley stations.

A comparison of figures 10, 11, and 12 with figures 5 and 6 brings out the great difference in diurnal changes in temperature at Medford and Pomona. The influence of the longer nights at Pomona is evident from the late occurrence of the minimum temperature and the earlier time of occurrence of the maximum temperature, as compared with Medford.

The greatest difference in minimum temperature observed during the season at the stations on Coker Butte, at the east side of the valley, was 8.9° F. in the 175 feet vertical distance between stations 2 and 4, on April 28. The difference between the minimum temperatures at the base and summit stations on this date was 8.2° F.

The greatest difference in minimum temperature during the season at the wireless tower was 13.4° F. between the base and 300-foot stations on April 28.

On the west side of the valley the greatest inversion during the season was 11.8° F. between stations 6 and 8 (190 feet difference in elevation) on April 19.

It will be noted that the average temperature inversion in the Rogue River Valley in spring is much less than the average inversion during the winter months in the Pomona Valley.

MAXIMUM TEMPERATURES.

On clear days the maximum temperature at the 300-foot elevation on the wireless tower was from 3° to 6° F. lower than at the base, but there was seldom more than one or two degrees difference between the maxima at the 300-foot level and at the 150-foot level. The difference in maximum temperature in the 180 feet vertical distance between stations 7 and 8 varied from 2° to 5° F. on clear days, and on one day the difference was 6° F.

On the east side of the valley the maximum temperature at station 1, on the summit of Coker Butte, was consistently higher than the maximum at station 4 at the base of the hill, 275 feet below. Maximum temperatures at both stations 2 and 3 were the same or higher than those at station 4. This was probably due to the fact that stations 2 and 3 were located on the steep westward-facing slope, and station 1 on the summit, of Coker Butte. The convective currents caused by the rays of the afternoon sun, shining almost perpendicularly on the slope, probably were considerably warmer than the free air at the same elevation over the valley floor.

TIME OF OCCURRENCE OF MINIMUM TEMPERATURE.

The average time of occurrence of the minimum temperature on 20 clear nights during April and May, 1918, at most of the hill and valley stations shown in figure 9 are given below. These data were taken from thermograph records, which were checked daily.

Stations.	Elevation (m. s. l.).	Average time of occurrence of minimum temperature.
	Feet.	*A. m.*
1	1,650	6.27
4	1,375	5.58
300 feet on tower	1,560	6.54
150 feet on tower	1,410	6.45
5 (base of tower)	1,260	5.50
8	1,450	6.24
7	1,270	5.32

The minimum temperature occurred at the top of the wireless tower more than an hour later than at the base, but there was only nine minutes' difference between the 150-foot level and the top (300 feet). At the east side of the valley the minimum occurred 29 minutes later at the summit of Coker Butte than at the base, 275 feet below. On the west side of the valley the minimum temperature occurred 52 minutes later at station 8 on the hillside than at station 7, 180 feet lower.

OBSERVATIONS DURING 1919 SEASON.

During the 1919 season a station was established on the summit, and two stations at the base of another hill in the Rogue River Valley, about five miles south of the wireless tower, where the 1918 observations were obtained. (See figs. 13 and 14.) A profile of this hill, showing the locations of the stations, is shown in figure 15. Minimum temperatures registered on clear nights during the spring frost season are shown in Table 4.

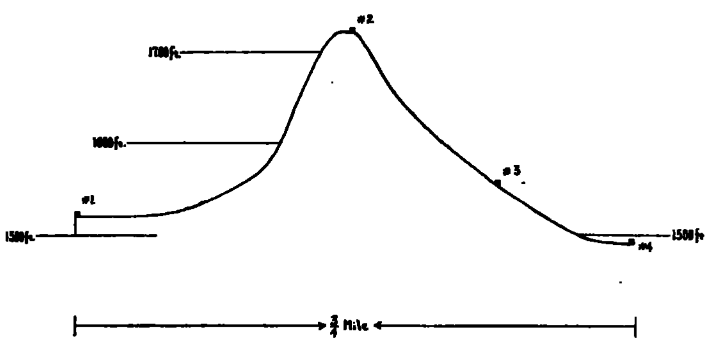

FIG. 15.—Profile of hill near Medford, Oreg., showing locations of temperature survey stations (see figs. 13 and 14). Elevations in feet above mean sea level.

Minimum temperatures on clear nights averaged only about 4° F. higher at the top of the hill than at the base, the difference in elevation being about 200 feet. This is in marked contrast to the temperature inversions observed at Pomona, where the average difference in 225 feet vertical elevation was 16.9° F.

The greatest difference between minimum temperatures at stations 1 and 2 during the season was 6.9° F., as against a maximum difference of 28° F. in 225 feet vertical elevation on San Jose Hill at Pomona.

The average difference in minimum temperature between the base station and station 3, 165 feet below the summit of the hill, was 4.1° F., only 0.2° F. less than the average difference in the 200 feet between stations 2 and 4. The greatest difference in minimum temperature on the hillside during the season was 7.1° F. between stations 1 and 3, on May 7. On this night the minimum temperature at the summit was 0.7° F. lower than the minimum at station 3, 165 feet below, on the hillside. While the average minimum at station 3 was not higher than the average minimum at station 2, on the summit, a station 50 feet or less below the summit probably would have shown a higher average minimum temperature on clear nights than the summit station.

In the three different locations where minimum temperatures were obtained on the slopes and tops of isolated hills or ridges rising from the valley floor the observations indicate that the highest average minimum temperature is found below the summit of the hill, on the steep slope. (See fig. 9 and Table 2.)

This is probably due to a freer interchange between the surface air and the free air over the valley on the slope than on the hilltop. On calm nights the air cooled through contact with a well-rounded hilltop probably does not drain away to lower levels until its density has become considerably greater than the density of the free air at the same level. The greater the area of the hilltop and the more gradual the slope near the highest point, the greater will be the depression of the temperature of the surface air below that of the free air at the same elevation, provided the air is calm.

FACTORS WHICH DETERMINE AMOUNT OF INVERSION.

It was mentioned at the beginning of this paper that about sunset on a clear, calm day the air for a considerable distance above the ground has nearly the temperature due to a complete mixing; that is, a decrease in temperature with elevation of about 1° F. per 188 feet. Since local nocturnal temperature inversions are caused by the lowering of the temperature of the surface air below that of the air at higher elevations[5] (not by the temperature of the air at higher levels being raised above the temperature of the surface air), it follows that, other conditions being the same, the greater the fall in temperature near the ground the greater will be the temperature inversion. The amount of fall in temperature in the surface air during the night depends on the rate at which the ground cools by radiation, which in turn depends on the temperature of the ground and the absolute humidity.

The greatest inversions in temperature were found, both at Pomona and Medford, on clear, calm nights when the dewpoint was low, following warm days. The smallest inversions on clear nights occurred when the dewpoint was high, and following days when the maximum temperature was relatively low. The wind was seldom strong enough on clear nights at either place to have much effect on the amount of inversion.

Since the greatest inversions occur following clear, still days, with high maximum temperature, the minimum temperatures on the valley floor on such nights are generally above the danger point. The most severe frosts usually occur on nights following cold, windy, and oftentimes cloudy, days. At such times the inversion is usually considerably less than the average.

The relation between the amount of nocturnal temperature inversion on a given night, and the maximum temperature of the preceding day, at Pomona, is shown in figure 16. Other factors influencing the amount of inversion, such as the amount of wind, cloudiness during a portion of the night, and the absolute humidity, are not represented in these graphs.

[5] H. J. Cox, in "Thermal Belts and Inversions of Temperature in the North Carolina Mountain Region" (MO. WEATHER REV., December, 1919: 47:879-880), states that when inversions were noted under cyclonic conditions, the temperature rose more rapidly at the summit than at the base, thus increasing the inversion. On the lower hills of the Pacific coast the approach of a cyclonic area usually prevents the development of temperature inversions through cloudiness and wind.

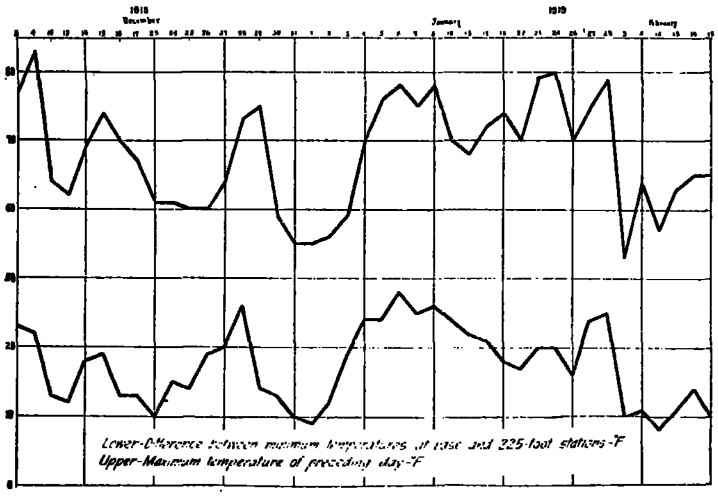

FIG. 16.—Relation of the amount of temperature inversion between the base and 225-foot stations on the slope of San Jose Hill, near Pomona, Calif. (see figs. 1 and 2), to the maximum temperature of the previous day at the base station. In nearly every case, lack of agreement between the trend of the data on individual dates is directly traceable to the influence of wind, clouds, or valley fog during the night.

A fairly accurate forecast of the amount of temperature inversion to be expected on the following night at Pomona, may be made as soon as the maximum temperature has occurred. The relation between the amount of temperature inversion and the daily range in temperature is still more marked.

The evening weather map preceding nights with large temperature inversions at Medford, practically always shows a stagnant condition, with slight pressure gradients. When the Arizona LOW is weak, or entirely absent, a large temperature inversion will practically always occur, provided the sky is clear during all or a part of the night. This may take place when there is no well-defined HIGH on the coast, but in this case there is no danger of frost. The greatest inversions usually occur when there is a large, weak HIGH central over northern California and southern Oregon, with no depression over Arizona, or one of only slight intensity.

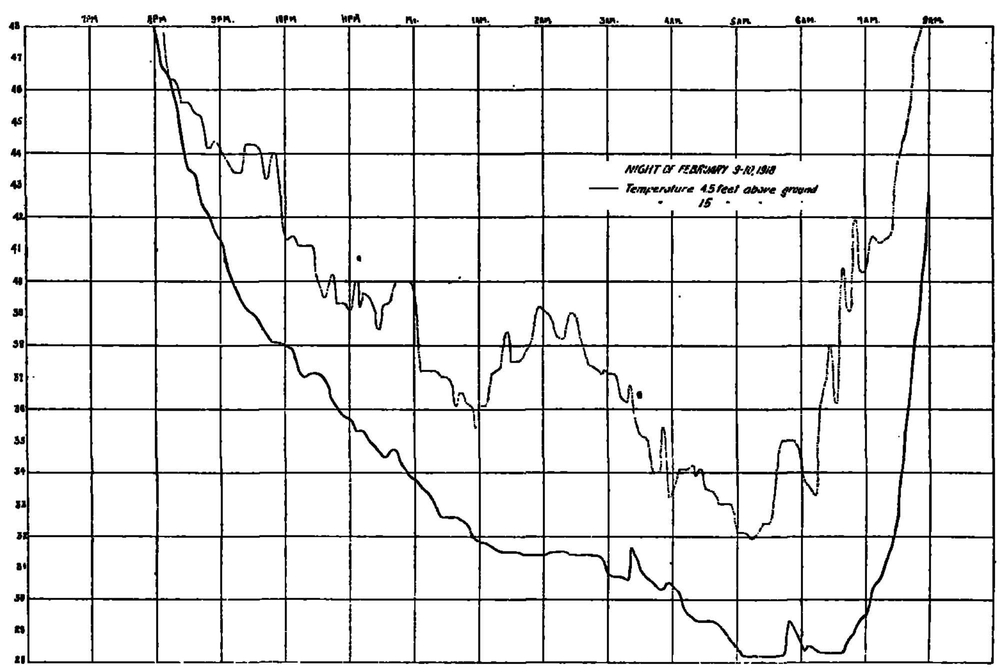

FIG. 17.—Corrected thermograms from stations 4.5 feet (solid line) and 15 feet (dotted line) above the ground on a tower in an orange grove near Pomona, Calif., for the night of February 9-10, 1918.

TEMPERATURE INVERSIONS NEAR THE VALLEY FLOOR.

Observations on the hillsides at Pomona indicated that the stratum of cold air near the ground on frosty nights was extremely thin. In order to obtain additional information as to the depth of this cold air near the ground, minimum thermometers and 29-hour thermographs were installed during the 1917–18 frost season, at elevations of 4½ and 15 feet above the ground on a 15-foot tower in an orange grove near the lowest portion of the valley. The ground within a radius of 1,000 feet from the tower was practically level, and the nearest steep slope was about a mile distant.

Minimum temperatures registered on this tower on 14 clear nights during the season are shown in Table 5. The average difference between minimum temperatures at the two stations on these nights was 1.6° F. The maximum difference was 3.7° on February 10. As the upper station was only slightly above the tops of the trees and the lower station was at about the height of the lowest fruit on the trees, minimum temperatures at the two levels indicate quite accurately the lowest air temperatures to which the fruit at the two elevations was subjected. The outside fruit near the top of the tree is less sheltered from the sky than the fruit lower down, and the higher rate of radiation probably offsets, to some extent, the advantage of a higher air temperature.

Differences between temperature conditions at the two elevations on individual nights are usually not adequately shown by the minimum temperatures alone. Fluctuations in temperature of 4° or more were common at the upper station, without corresponding changes at the lower station (see fig. 17). At times during the night differences as great as 7° in the 10.5 feet between the two stations were recorded.

During the 1918–19 season, records were obtained on a similar tower at practically the same location. Minimum thermometers were installed at elevations of 2, 5, 9, 12, and 15 feet above the ground. Wide, thin boards, placed directly over each instrument, were used to provide shelter from the sky and to protect them from dew and frost.

On 13 clear nights during January and February, 1919, the minimum temperature at the 15-foot elevation averaged 3.4° F. higher than the minimum at the 2-foot station. Differences on individual nights were as high as 6.5° F. Daily minimum temperatures for all elevations are given in Table 6. The duration of the minimum temperature near the tops of the trees was practically always much shorter than near the ground.

TEMPERATURE INVERSION ON 40-FOOT TOWER.

During February, 1919, the Pomona Frost Protective Association furnished funds for the erection of two towers, 30 and 40 feet high, respectively, for a study of orchard heating. Thermometers and 29-hour thermographs were placed in small shelters on both towers at 5-foot intervals, from 5 feet above the ground to the tops

[To face p. 144.]

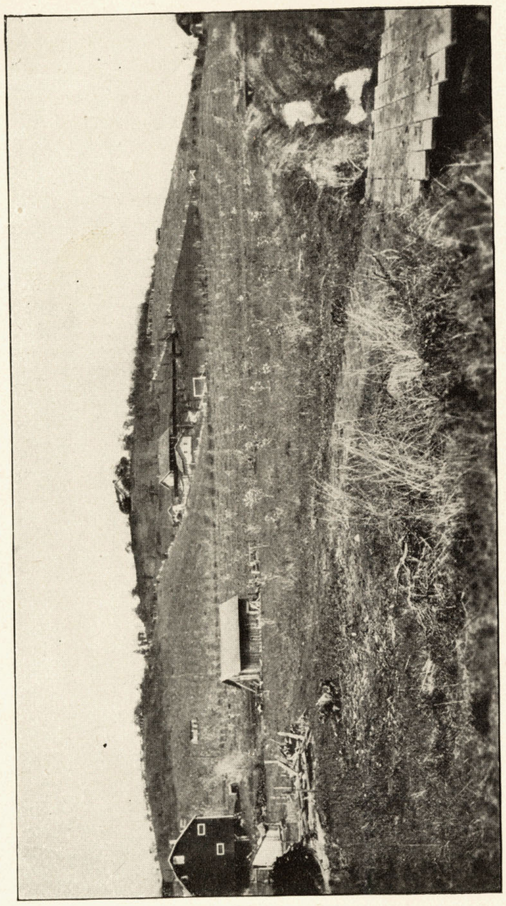

FIG. 13.—View of hill near Medford, Oreg., shown in figure 15, from station 1.

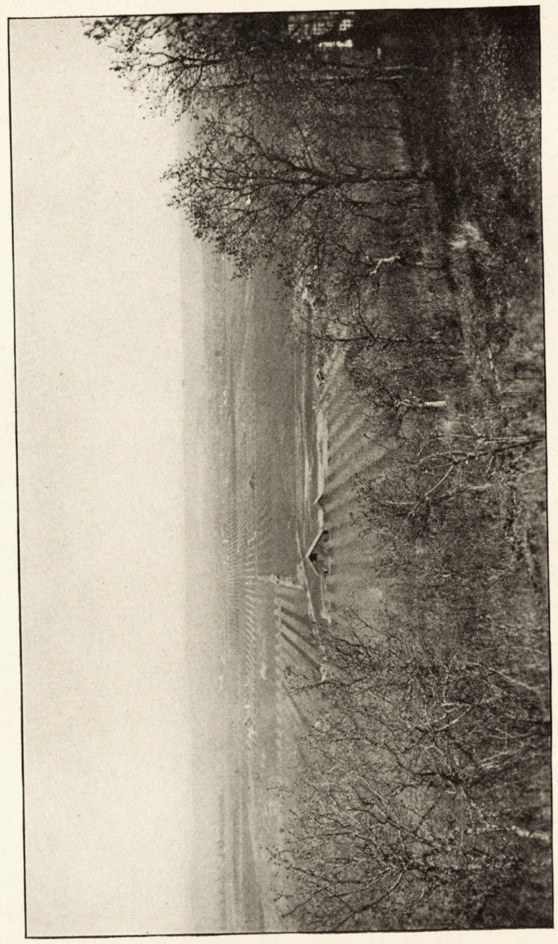

FIG. 14.—Rogue River Valley from summit of hill shown in figures 13 and 15. View taken from station 2.

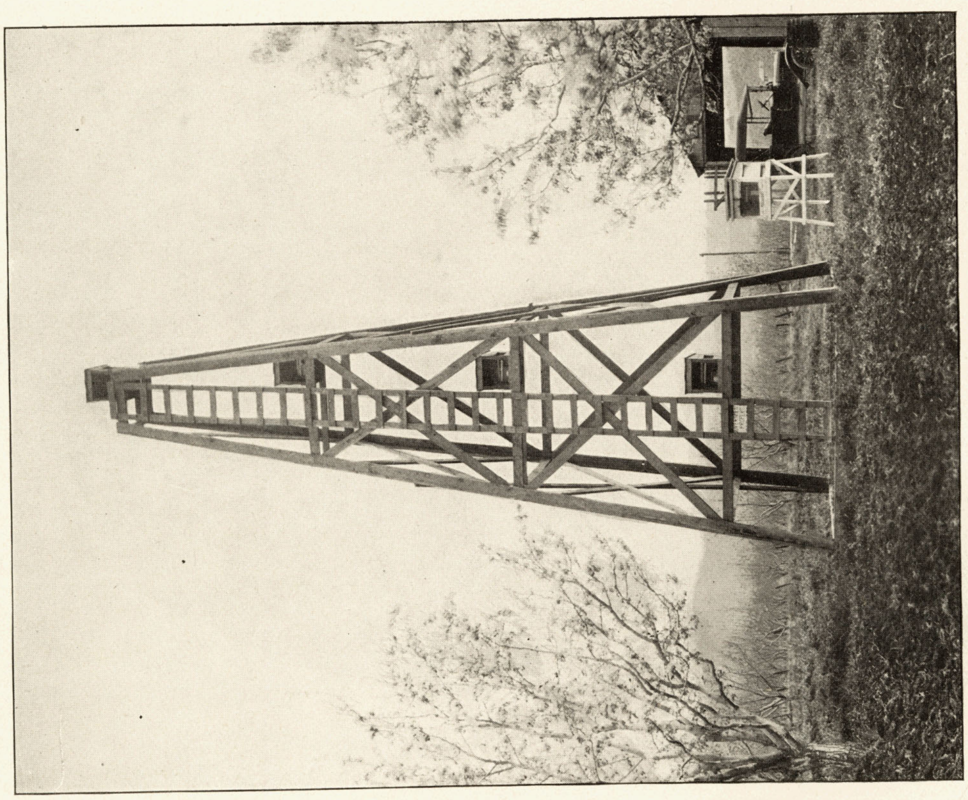

FIG. 20.—View of 35-foot instrument tower near Medford, Oreg., on which minimum temperatures shown in Table 8 were obtained.

of the towers. The 40-foot tower was located in an orchard which was equipped with orchard heaters. Both towers were located on gently sloping ground, about half way between the base of the foothills and the lowest part of the valley (see fig. 1). Minimum temperatures at various elevations on the 40-foot tower during 13 clear nights in February, 1919, and 39 clear nights during the 1919–20 frost season, are given in Table 7. The difference in minimum temperature between the base and top of this tower was affected on a few nights by firing, but the records on the 30-foot check tower, around which no orchard heaters were burned, show that the influence of these brief periods of firing was slight and may be disregarded.

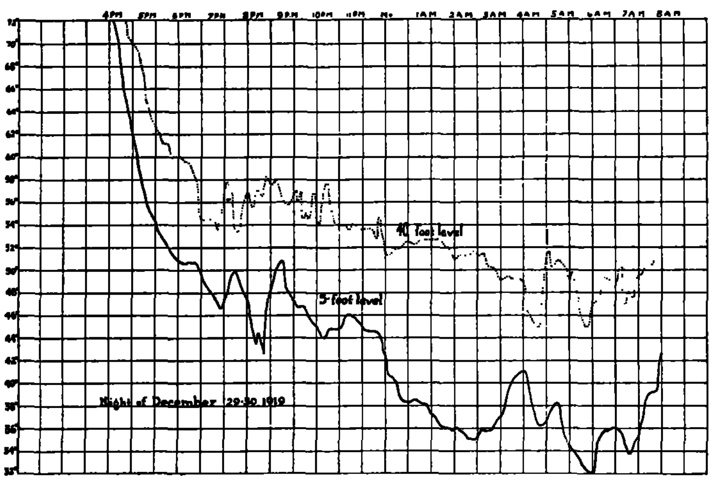

FIG. 18.—Corrected thermograms from 5-foot and 40-foot levels on a tower in an orange grove near Pomona, Calif., during the night of December 29–30, 1919. The temperature inversion on this night was above the average.

The average difference in minimum temperature in the 35 feet between the 5-foot station and top of the tower was 8.4° F.; slightly more than 1° for each 5 feet. The average rate of increase in minimum temperature from the 5-foot station to the 40-foot station, was quite uniform.

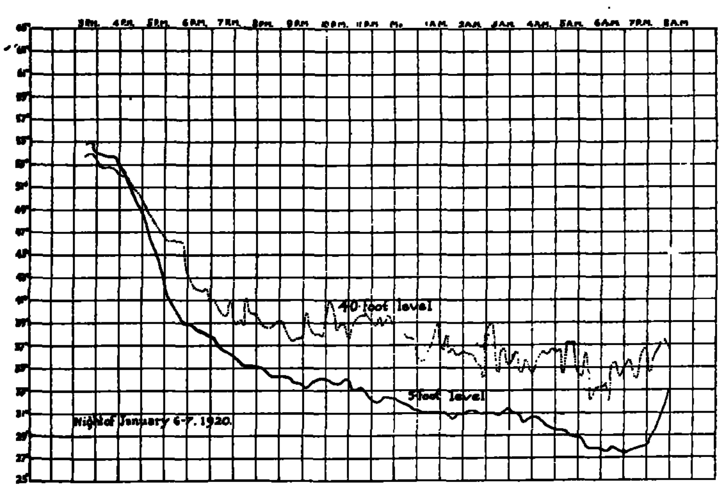

FIG. 19.—Corrected thermograms from 5-foot and 40-foot levels on a tower in an orange grove near Pomona, Calif., during the night of January 6–7, 1920. The temperature inversion on this night was below the average.

The greatest difference in minimum temperature was 15° F., on the morning of January 18, 1920. The maximum temperature of the preceding day was 85.4° F.

Corrected thermograms registered at the 5-foot and 40-foot stations on two nights, with large and small temperature inversions, respectively, are shown in figures 18 and 19.

OBSERVATIONS ON TOWERS AT MEDFORD.

In April, 1919, two 35-foot wooden towers were erected in pear orchards near Medford, Oreg., for use in the continuation of the orchard-heating investigations begun at Pomona (see fig. 20). These towers were located on gently sloping ground, near the lowest part of the upper valley. Minimum thermometers and 29-hour thermographs were installed in small shelters on these towers at elevations of 5, 15, 25, and 35 feet above the ground. Daily minimum temperatures at stations on the tower in the orchard which was not fired, for all clear nights during the 1919 and 1920 frost seasons, are given in Table 8.

The average difference in minimum temperature between the 5-foot and 35-foot stations was 4.2° F., slightly more than half the difference between the same stations on the Pomona tower. At Pomona differences between stations were quite uniform; at Medford the differences in minimum temperature between succeeding stations decreased from the base to the top of the tower. On several clear nights the minimum at the 35-foot level was lower than the minimum at the 25-foot level. The greatest difference in minimum temperature between the 5-foot and 35-foot stations at Medford was 6.8° F. The greatest difference between the same stations on the Pomona tower was 12° F.

CONCLUSION.

The average nocturnal temperature inversion on clear nights at Pomona during the winter months, is about double that at Medford in spring, probably on account of the lower humidity and greater daily range in temperature at Pomona. At both places the stratum of cold air over the valley floor on frosty nights is extremely thin.

The greatest inversions occur at both Pomona and Medford following warm days, and as a general rule the minimum temperature in the coldest section in the valley is not low enough to cause damage on such nights. On nights when extremely low temperatures are recorded on the lower ground, there is likely to be some damage on the hillsides, since on the coldest nights the temperature inversion is usually slight.

Observations on the 300-foot wireless tower, located on the valley floor near Medford, about equidistant from the foothills on either side, show that the minimum temperature occurs more than an hour later at the 150-foot level than at the base. This represents the length of time after sunrise required to overcome the inversion and bring the stratum of air below the 150-foot station approximately into adiabatic equilibrium.

A comparison between the temperature differences on the wireless tower and on the hillsides on either side of the valley at Medford indicates that during the night the hillside temperatures are somewhat lower than the temperature of the free air at the same levels, as would be expected. The differences, however, are slight.

TABLE 1.—*Minimum temperatures on clear nights during winter of 1917–18 at hill and valley stations near Pomona, Calif.*

[Station numbers and elevations (m. s. l.); see fig. 1.]

Date.	2 (1,230 feet).	1 (1,400 feet).	Departure.	9 (825 feet).	8 (950 feet).	Departure.	7 (1,075 feet).	Departure.
1918.								
Jan. 6	34.7	51.0	+16.3	30.0	38.6	+ 8.6	41.1	+11.1
10	35.0	40.0	+ 5.0	28.8	39.0	+10.2	39.2	+10.4
11	27.5	43.0	+15.5	25.0	32.7	+ 7.7	36.3	+11.3
12	28.4	42.5	+14.1	25.1	34.8	+ 9.7	36.2	+11.1
14	34.6	43.0	+ 8.4	31.8	39.0	+ 7.2	40.2	+ 8.4
17	36.5	53.0	+13.5	32.2	43.8	+11.6	44.8	+12.6
18	35.8	51.0	+15.2	32.9	43.2	+10.3	44.2	+11.3
20	33.4	41.7	+ 8.3	25.0	38.0	+13.0	37.1	+12.1
21	27.1	42.0	+14.9	23.8	35.0	+11.2	39.0	+15.2
22	25.8	40.8	+15.0	23.0	33.1	+10.1	34.1	+11.1
23	24.5	45.5	+21.0	23.1	39.0	+15.9	40.8	+17.7
24	34.6	52.0	+17.4	29.8	43.7	+13.9	47.4	+17.6
27	36.4	41.0	+ 4.6	31.0	37.0	+ 6.0	39.0	+ 8.0
28	28.5	43.0	+14.5	21.3	34.0	+ 9.7	36.0	+11.7
29	27.5	44.0	+16.5	24.8	33.0	+ 8.2	35.9	+11.1
30	36.3	40.7	+ 4.4	33.7	41.0	+ 7.3	41.0	+ 7.3
31	33.0	43.0	+10.0	32.1	40.0	+ 7.9	40.0	+ 7.9
1918.								
Feb. 1	27.8	42.0	+14.2	26.2	38.7	+12.5	38.8	+12.6
2	28.6	45.0	+16.4	26.0	35.2	+ 9.2	36.2	+10.2
3	31.3	49.0	+17.7	28.1	39.0	+10.9	41.0	+12.9
4	32.0	54.0	+22.0	26.8	43.0	+16.2	42.1	+15.3
5	33.7	51.0	+17.3	30.0	39.1	+ 9.1	43.0	+13.0
6	33.7	44.8	+11.1	30.6	38.1	+ 7.5	41.0	+10.4
8	34.0	46.0	+12.0	32.9	41.3	+ 8.4	42.9	+10.0
9	35.3	49.0	+13.7	26.8	41.6	+14.8	48.0	+21.2
10	34.0	55.5	+21.5	28.0	49.8	+21.8	49.9	+21.9
11	29.7	51.0	+21.3	24.5	36.9	+12.4	42.0	+17.5
14	37.0	44.0	+ 7.0	32.9	41.8	+ 8.9	42.2	+ 9.3
16	28.2	45.0	+16.8	27.0	42.0	+15.0	41.4	+14.4
Average	31.9	46.0	+14.1	28.1	39.0	+10.9	40.7	+12.6

TABLE 2.—*Minimum temperatures on clear nights on south slope of San Jose Hill, near Pomona, Calif.*

[Stations (elevation above base station).]

Date.	Base.	25 feet.		50 feet.		75 feet.		100 feet.		125 feet.		175 feet.		225 feet.		275 feet.	
1918.																	
Dec. 3	32.0	36.1	+4.1	46.6	+14.6	48.9	+16.9	47.0	+15.0	53.2	+21.2	55.0	+23.0	55.0	+23.0	51.5	+19.5
4	31.0	35.5	+4.5	40.9	+ 9.9	41.6	+10.6	47.1	+16.1	51.2	+20.2	57.6	+26.6	53.2	+22.2	52.2	+21.2
10	28.9	31.9	+3.0	36.1	+ 7.2	36.0	+ 7.1	37.5	+ 8.6	40.2	+11.3	41.0	+12.1	42.2	+13.3	40.0	+11.1
13	29.0	31.5	+2.5	36.9	+ 7.9	36.1	+ 7.1	36.2	+ 7.2	39.0	+10.0	39.0	+10.0	41.0	+12.0	39.5	+10.5
14	30.1	34.0	+3.9	43.5	+13.4	43.8	+13.7	43.0	+12.9	48.0	+17.9	48.5	+18.4	48.0	+17.9	48.0	+17.9
15	29.4	33.0	+3.6	43.7	+14.3	42.8	+13.4	44.5	+15.1	47.1	+17.7	47.6	+18.2	48.3	+18.9	46.0	+16.6
16	30.8	34.8	+4.0	40.0	+ 9.2	40.6	+ 9.8	40.9	+10.1	43.3	+12.5	43.8	+13.0	43.9	+13.1	42.0	+11.2
17	27.8	30.8	+3.0	36.8	+ 9.0	37.3	+ 9.5	38.3	+10.5	38.9	+11.1	40.4	+12.7	40.9	+13.1	41.0	+13.2
23	25.2	28.1	+2.9	32.1	+ 6.9	31.8	+ 6.6	33.2	+ 8.0	34.1	+ 8.9	34.1	+ 8.9	35.1	+ 9.9	33.5	+ 8.3
24	21.0	28.7	+4.7	36.0	+12.0	34.1	+10.1	35.2	+11.2	37.9	+13.9	38.7	+14.7	38.9	+14.9	37.9	+13.9
25	21.9	23.1	+1.2	30.2	+ 8.3	30.2	+ 8.3	31.1	+ 9.2	34.9	+13.0	35.8	+13.9	36.1	+14.2	35.3	+13.4
26	21.5	24.5	+3.0	36.1	+14.6	36.8	+15.3	36.8	+15.3	38.5	+17.0	40.2	+18.7	40.9	+19.4	39.1	+17.6
27	24.1	29.7	+5.6	37.3	+13.2	38.0	+13.9	40.8	+16.7	43.3	+19.2	45.1	+21.0	44.3	+20.2	42.1	+18.0
28	24.7	29.8	+5.1	44.0	+19.3	44.0	+19.3	45.8	+21.1	48.2	+25.5	49.9	+25.2	51.1	+26.4	45.9	+21.2
29	24.3	27.2	+2.9	35.8	+11.5	34.7	+10.4	35.3	+11.0	38.1	+13.8	38.1	+13.8	38.2	+13.9	38.1	+13.8
30	19.9	22.0	+2.1	26.9	+ 7.0	26.1	+ 6.2	28.1	+ 8.2	32.5	+12.6	33.1	+13.2	33.2	+13.3	30.9	+11.0
31	21.8	21.2	−0.6	27.8	+ 6.0	26.7	+ 4.9	29.5	+ 7.7	31.4	+ 9.6	31.3	+ 9.5	32.1	+10.3	30.2	+ 8.4
Jan. 1	19.8	21.0	+1.2	26.1	+ 6.3	25.1	+ 5.3	26.1	+ 6.3	28.0	+ 8.2	28.2	+ 8.4	29.1	+ 9.3	29.1	+ 9.3
2	19.9	21.3	+1.4	27.0	+ 7.1	27.0	+ 7.1	28.6	+ 8.7	31.0	+11.1	31.2	+11.3	31.7	+11.8	30.6	+10.7
3	21.0	24.0	+3.0	31.0	+10.0	32.1	+11.1	33.9	+12.9	35.5	+14.5	36.5	+15.5	39.8	+18.8	39.2	+18.2
4	25.1	30.5	+5.4	41.7	+16.6	42.0	+16.9	42.7	+17.6	48.0	+22.9	48.8	+23.7	49.1	+24.0	48.0	+22.9
5	26.0	33.0	+7.0	42.9	+16.9	42.5	+16.5	42.7	+16.7	48.0	+22.0	49.0	+23.0	50.1	+24.1	49.9	+23.9
6	21.1	25.0	+3.9	33.3	+12.2	36.9	+15.8	40.8	+19.7	45.0	+23.9	47.0	+25.9	49.1	+28.0	45.0	+23.9
7	22.2	25.6	+3.4	35.0	+12.8	37.3	+15.1	41.0	+18.8	43.9	+21.7	45.0	+22.8	47.0	+24.8	43.7	+21.5
8	22.0	27.5	+5.5	39.2	+17.2	40.0	+18.0	40.0	+18.0	46.5	+24.5	47.2	+25.2	48.1	+26.1	47.7	+25.7
12	27.7	31.0	+3.3	36.1	+ 8.4	36.8	+ 9.1	38.9	+11.2	40.0	+12.3	40.4	+12.7	41.1	+13.4	40.6	+12.9
13	24.9	28.4	+3.5	38.6	+13.7	40.0	+15.1	40.1	+15.2	46.4	+21.5	46.8	+21.9	46.9	+22.0	45.0	+20.1
14	21.2	25.1	+3.9	34.2	+13.0	34.8	+13.6	35.8	+14.6	41.0	+19.8	41.9	+20.7	42.0	+20.8	41.9	+20.7
15	21.5	27.2	+5.7	38.5	+17.0	39.0	+17.5	41.9	+20.4	44.0	+22.5	44.0	+22.5	45.9	+24.4	40.3	+18.8
18	28.5	32.1	+3.6	41.0	+12.5	41.6	+11.1	41.8	+13.3	44.6	+16.1	45.8	+17.3	47.0	+18.5	44.8	+16.3
22	31.9	35.1	+3.2	43.1	+11.2	42.8	+10.9	44.1	+12.2	46.9	+15.0	49.9	+18.0	49.3	+17.4	49.1	+17.2
23	29.8	34.1	+4.3	40.1	+10.3	41.0	+11.2	45.7	+15.9	49.5	+19.7	49.9	+20.1	50.3	+20.5	49.1	+19.3
24	28.1	32.0	+3.9	42.0	+13.9	43.0	+14.9	43.8	+15.7	46.7	+18.6	47.1	+19.0	48.4	+20.3	47.0	+18.9
26	25.3	29.0	+3.7	36.1	+10.8	35.2	+ 9.9	36.4	+11.1	37.3	+12.0	39.0	+13.7	41.0	+15.7	39.0	+13.7
27	26.0	31.0	+5.0	43.4	+17.4	42.2	+16.2	44.0	+18.0	45.2	+19.2	47.0	+21.0	50.0	+24.0	45.3	+19.3
28	24.1	32.9	+8.8	42.7	+18.6	42.0	+17.9	44.8	+20.7	47.8	+23.7	48.1	+24.0	49.0	+24.9	48.0	+23.9
Feb. 3	27.3	29.7	+2.4	34.3	+ 7.0	33.6	+ 6.3	34.9	+ 7.6	37.6	+10.3	37.0	+ 9.7	37.8	+10.5	34.7	+ 7.4
4	26.1	29.1	+3.0	34.3	+ 8.2	33.2	+ 7.1	34.0	+ 7.9	36.0	+ 9.9	36.5	+10.4	37.1	+11.0	36.8	+10.7
12	29.0	30.4	+1.4	34.4	+ 5.4	33.2	+ 4.2	35.3	+ 6.3	36.2	+ 7.2	37.0	+ 8.0	37.5	+ 8.5	36.9	+ 7.9
13	27.7	29.8	+2.1	35.8	+ 8.1	34.8	+ 7.1	36.7	+ 9.0	38.0	+10.3	38.3	+10.6	39.1	+11.4	37.1	+ 9.4
14	28.2	31.1	+2.9	37.4	+ 9.2	37.1	+ 8.9	38.5	+10.3	40.3	+12.1	40.8	+12.6	41.9	+13.7	39.3	+11.1
15	31.1	33.9	+2.8	38.8	+ 7.7	37.6	+ 6.5	38.0	+ 6.9	39.5	+ 8.4	40.5	+ 9.4	41.0	+ 9.9	40.9	+ 9.8
16	29.5	32.7	+3.2	43.1	+13.6	41.2	+11.7	42.1	+12.6	42.9	+13.4	42.8	+13.3	42.7	+13.2	42.6	+13.1
18	27.8	30.1	+2.3	33.1	+ 5.3	32.0	+ 4.2	33.4	+ 5.6	34.9	+ 7.1	35.3	+ 7.5	35.8	+ 8.0	34.2	+ 6.4
19	26.0	28.0	+2.0	35.0	+ 9.0	34.0	+ 8.0	36.0	+10.0	36.7	+10.7	37.1	+11.1	38.0	+12.0	36.7	+10.7
Average	25.9	29.4	+3.5	37.2	+11.3	37.2	+11.3	38.6	+12.7	41.4	+15.5	42.3	+16.4	42.8	+16.9	41.2	+15.3

TABLE 3.—*Medford, Oreg., minimum temperatures and temperature inversions on clear nights at stations shown in fig. 9.*

	Stations.							Base wireless.	150 feet.		300 feet.		6.	7.		8.	
	4.	3.		2.		1.											
Apr. 1	37.5					38.0	+0.5	33.9	39.1	+ 5.2	38.4	+ 4.5	33.6	33.3	−0.3	36.1	+ 2.5
2	25.9					28.4	+2.5	22.9	29.0	+ 6.1	29.8	+ 6.9	23.4	25.0	+1.6	27.3	+ 3.9
3	22.0					24.1	+2.1	19.2	25.8	+ 6.6	26.8	+ 7.6	19.7	21.2	+1.5	24.0	+ 4.3
4	24.1					27.7	+3.6	22.9	28.8	+ 5.9	33.8	+10.9	23.0	24.0	+1.0	28.0	+ 5.0
5	30.3					33.0	+2.7	28.9	33.0	+ 4.1	34.4	+ 5.5	28.9	30.7	+1.8	33.0	+ 4.1
6	37.8					38.0	+0.2	36.4	39.3	+ 2.9	40.3	+ 3.9	35.1	36.1	+1.0	38.7	+ 3.6
10	35.2					37.1	+1.9	32.8	33.0	+ 0.2	37.7	+ 4.9	31.8	32.7	+0.9	36.4	+ 4.6
11	39.0					39.1	+0.1	38.0	39.0	+ 1.0	42.1	+ 4.1	37.0	37.1	+0.1	38.5	+ 1.5
12	37.0	38.4	+1.4			38.1	+1.1	37.0	39.0	+ 2.0	39.4	+ 2.4	36.1	36.9	+0.8	38.0	+ 1.9
13	32.2	33.0	+0.8			32.4	+0.2	31.0	32.0	+ 1.0	33.0	+ 2.0	30.4	30.3	−0.1	30.3	− 0.1
15	30.1	31.0	+0.9			30.3	+0.2	27.0	30.1	+ 3.1	31.6	+ 4.6	27.3	28.1	+0.8	29.1	+ 1.8
18	32.8	37.0	+4.2	37.5	+4.7	37.0	+4.2	29.9	38.0	+ 8.1	38.2	+ 8.3	30.0	32.9	+2.9	37.2	+ 7.2
19	40.7	43.1	+2.4	44.0	+3.3	43.0	+2.3	35.5	44.9	+ 9.4	46.9	+11.4	33.0	35.9	+2.9	44.8	+11.8
20	37.4	44.1	+6.7	44.1	+6.7	43.2	+5.8	43.4	45.3	+ 1.9	46.7	+ 3.3	34.1	37.0	+2.9	44.0	+ 9.9
21	40.1	46.1	+6.0	47.0	+6.9	46.1	+6.0	36.6	46.1	+ 9.5	48.0	+11.4	36.8	40.1	+3.3	46.5	+ 9.7
22	35.1	39.0	+3.9	39.7	+4.6	39.0	+3.9	30.1	40.9	+10.8	42.1	+12.0	30.4	32.9	+2.5	39.2	+ 8.8
23	35.0	36.4	+1.4	37.0	+2.0	37.0	+2.0	31.8	39.1	+ 7.3	38.3	+ 6.5	30.3	32.2	+1.9	37.0	+ 6.7
26	30.1	34.2	+4.1	36.7	+6.6	37.0	+6.9	26.0	33.9	+ 7.9	38.7	+12.7	25.8	28.1	+2.3	34.0	+ 8.2
27	30.3	38.0	+7.7	38.1	+7.8	36.7	+6.4	27.0	36.9	+ 9.9	39.1	+12.1	25.9	29.1	+3.2	37.0	+11.1
28	32.1	39.9	+7.8	41.0	+8.9	40.3	+8.2	29.4	40.9	+11.5	42.8	+13.4	29.0	34.0	+5.0	39.8	+10.8
29	38.8	43.4	+4.6	44.0	+5.2	43.1	+4.3	35.0	45.2	+10.2	46.0	+11.0	34.8	36.7	+1.9	44.4	+ 9.6
30	35.5	39.8	+4.3	40.4	+4.9	41.6	+6.1	31.9	40.7	+ 8.8	43.4	+11.5	31.3	35.0	+3.7	39.0	+ 7.7
May 1	41.2	40.1	−1.1	42.0	+0.8	41.6	+0.4	33.9	40.3	+ 6.4	44.0	+10.1	32.7	35.9	+3.2	41.0	+ 8.3
2	45.1	49.0	+3.9	49.6	+4.5	50.8	+5.7	39.9	50.5	+10.6	53.1	+13.2	38.0	41.1	+3.1	48.0	+10.0
3	42.3	47.9	+5.6	49.9	+7.6	48.9	+6.6	38.3	48.2	+ 9.9	51.0	+12.7	36.8	39.7	+2.8	46.7	+ 9.9
4	38.2	41.9	+3.7	43.0	+4.8	43.3	+5.1	34.1	42.9	+ 8.8	43.0	+ 8.9	33.4	36.0	+2.6	40.5	+ 7.1
5	34.3	37.5	+3.2	39.0	+4.7	39.0	+4.7	30.6	39.2	+ 8.6	40.3	+ 9.7	29.4	32.0	+2.6	36.3	+ 6.9
6	33.1	35.1	+2.0	35.2	+2.1	35.0	+1.9	29.0	37.1	+ 8.1	39.4	+10.4	29.3	32.2	+2.9	36.8	+ 7.5
7	36.0	40.3	+4.3	41.0	+5.0	40.9	+4.9	32.3	41.2	+ 8.9	43.0	+10.7	31.7	34.0	+2.3	39.6	+ 7.9
11	34.4	37.0	+2.6	37.8	+3.4	38.0	+3.6	31.8	39.1	+ 7.3	40.1	+ 8.3	32.0	33.3	+1.3	38.0	+ 6.0
12	39.1	43.0	+3.9	43.3	+4.2	43.8	+4.7	35.6	43.6	+ 8.0	47.0	+11.4	34.8	37.1	+2.3	43.1	+ 8.3
13	40.0	44.0	+4.0	45.9	+5.9	45.6	+5.6	36.9	42.5	+ 5.6	48.7	+11.8	35.3	37.5	+2.2	44.0	+ 8.7
Average	35.1	38.1	+3.0	38.9	+3.8	38.7	+3.6	32.2	38.9	+ 6.7	40.8	+ 8.6	31.3	33.4	+2.1	38.0	+ 6.7

TABLE 4.—*Minimum temperatures and temperature inversions on clear nights at stations shown in fig. 15.*

Date.	Stations.						
	1. (1,520 feet.)	2. (1,720 feet.)		3. (1,555 feet.)		4. (1,490 feet.)	
Apr. 1	35.4	40.1	+4.7	39.9	+4.5	36.2	+0.8
7	31.0	32.2	+1.2	32.0	+1.0	30.8	−0.2
8	27.6	30.6	+3.0	30.2	+2.6	28.2	+0.6
11	27.9	30.0	+2.1	30.2	+2.3	28.1	+0.2
12	31.1	35.1	+4.0	35.1	+4.0	31.2	+0.1
14	26.8	29.1	+2.3	28.9	+2.1	28.0	+1.2
20	30.6	33.1	+2.5	33.6	+3.0	31.4	+0.8
22	33.0	37.1	+4.1	36.6	+3.6	33.1	+0.1
26	30.9	33.9	+3.0	34.6	+3.7	31.0	+0.1
28	37.9	43.0	+5.1	42.9	+5.0	37.1	−0.8
29	36.8	43.0	+6.2	41.2	+4.6	37.4	+0.6
30	41.0	47.4	+6.4	46.1	+5.1	41.0	−0.0
May 1	37.9	43.0	+5.1	43.9	+6.0	37.2	−0.7
3	32.7	37.0	+4.3	36.6	+3.9	32.0	−0.7
4	32.0	37.0	+5.0	36.2	+4.2	31.0	−1.0
5	31.0	36.2	+5.2	37.3	+6.3	30.0	−1.0
6	34.1	41.0	+6.9	39.8	+5.7	35.0	+0.9
7	36.5	42.9	+6.4	43.6	+7.1	36.8	+0.3
10	30.8	35.0	+4.2	34.7	+3.9	30.2	−0.6
Average	32.9	37.2	+4.3	37.0	+4.1	32.9	−0.0

TABLE 5.—*Minimum temperatures on clear nights on 15-foot tower in orange grove, near Pomona, Calif.*

Date.	Elevation above ground.		Departure.
	4.5 feet.	15 feet.	
1918.			
Jan. 23	23.8	25.2	+1.4
24	30.0	32.2	+2.2
28	26.1	26.1	0.0
29	25.2	26.0	+0.8
30	33.7	35.0	+1.3
31	33.7	34.8	+1.1
Feb. 1	27.9	28.7	+0.8
2	26.9	28.0	+1.1
3	28.7	30.0	+1.3
4	28.0	30.0	+2.0
5	31.0	33.2	+2.2
6	32.0	34.0	+2.0
10	28.2	31.9	+3.7
11	25.7	27.9	+2.2
12	39.0	40.1	+1.1
13	36.9	38.5	+1.6
14	33.6	35.0	+1.4
16	27.9	30.1	+2.2
17	26.8	29.0	+2.2
19	25.7	26.1	+0.4
Average	29.5	31.1	+1.6

TABLE 6.—*Minimum temperatures on clear nights on 15-foot tower in orange grove, near Pomona, Calif.*

Date.	Elevation above ground.								
	2 feet.	5 feet.		9 feet.		12 feet.		15 feet.	
1919.									
Jan. 12	29.0	29.8	+0.8	30.3	+1.3	30.0	+1.0	30.4	+1.4
13	26.2	27.0	+0.8	27.9	+1.7	28.0	+1.8	29.0	+2.8
14	22.2	22.8	+0.6	23.7	+1.5	23.9	+1.7	25.0	+2.8
15	24.2	25.1	+0.9	27.4	+3.2	28.0	+3.8	29.9	+5.7
18	29.8	30.1	+0.3	30.9	+1.1	31.1	+0.2	32.0	+2.2
22	32.5	33.5	+1.0	34.0	+1.5	34.1	+1.6	35.5	+3.0
23	31.1	32.3	+1.2	33.1	+2.0	34.9	+3.8	35.6	+4.5
24	28.5	29.3	+0.8	30.4	+1.9	30.7	+2.2	32.9	+4.4

Date.	Elevation above ground.								
	2 feet.	5 feet.		9 feet.		12 feet.		15 feet.	
1919.									
Jan. 26	26.3	27.0	+0.7	27.8	+1.5	27.8	+1.5	29.0	+2.7
27	26.9	28.0	+1.1	28.9	+2.0	29.0	+2.1	30.0	+3.1
28	25.2	27.0	+1.8	28.9	+3.7	29.4	+4.2	31.7	+6.5
Feb. 3	28.0	28.3	+0.3	29.0	+1.0	28.3	+0.3	29.7	+1.7
4	28.1	28.3	+0.2	29.7	+1.6	30.0	+1.9	31.0	+2.9
Average	27.5	28.3	+0.8	29.4	+1.9	29.6	+2.1	30.9	+3.4

46808—21——3

TABLE 7.—*Minimum temperatures on clear nights on 40-foot tower in orange grove, Pomona, Calif.*

Date.	Elevation above ground.														
	5 feet.	10 feet.		15 feet.		20 feet.		25 feet.		30 feet.		35 feet.		40 feet.	
1919.															
Feb. 13	32.0	33.0	+1.0	34.0	+2.0	34.0	+2.0	35.0	+3.0	35.4	+3.4	35.8	+3.8	37.0	+5.0
14	32.4	33.4	+1.0	34.1	+1.7	34.7	+2.3	36.1	+3.7	37.9	+5.5	39.1	+6.7	41.0	+8.6
15	33.8	34.8	+1.0	35.2	+1.4	35.4	+1.6	36.3	+2.5	37.0	+3.2	37.0	+3.2	38.0	+4.2
16	36.0	36.9	+0.9	39.1	+3.1	39.4	+3.4	40.3	+4.3	41.2	+5.2	42.0	+6.0	44.7	+8.7
18	32.3	32.4	+0.1	33.0	+0.7	32.9	+0.6	34.0	+1.7	35.0	+2.7	35.0	+2.7	36.0	+3.7
19	31.3	31.3	0.0	32.4	+1.1	32.4	+1.1	33.8	+2.5	35.9	+4.6	36.8	+5.5	38.0	+6.7
21	29.0	29.0	0.0	31.0	+2.0	31.0	+2.0	32.0	+3.0	32.7	+3.7	33.0	+4.0	35.0	+6.0
24	30.1	30.3	+0.2	31.4	+1.3	31.4	+1.3	32.8	+2.7	33.4	+3.3	33.6	+3.5	34.5	+4.4
25	31.0	32.0	+1.0	33.0	+2.0	32.6	+1.6	33.3	+2.3	34.5	+3.5	35.7	+4.7	38.9	+7.9
26	32.0	32.1	+0.1	33.1	+1.1	33.6	+1.6	34.9	+2.9	35.7	+3.7	36.2	+4.2	37.2	+5.2
27	39.0	39.0	0.0	40.3	+1.3	40.5	+1.5	41.7	+2.7	41.9	+2.9	41.0	+2.0	41.8	+2.8
28	34.0	34.0	0.0	35.0	+1.0	35.0	+1.0	36.8	+2.8	37.4	+3.4	38.0	+4.0	39.8	+5.8
Nov. 28	26.8	......	......	......	......	......	......	......	......	......	......	......	......	29.1	+2.3
29	27.0	......	......	......	......	......	......	......	......	......	......	......	......	32.1	+5.1
30	28.6	......	......	......	......	31.9	+3.3	......	......	......	......	......	......	34.9	+6.3
Dec. 3	35.0	......	......	......	......	40.2	+5.2	......	......	......	......	......	......	42.3	+7.3
10	31.1	......	......	......	......	34.1	+3.0	......	......	......	......	......	......	37.2	+6.1
11	30.0	......	......	......	......	35.8	+5.8	......	......	......	......	......	......	39.6	+9.6
14	27.6	......	......	......	......	30.0	+2.4	......	......	......	......	......	......	36.0	+8.4
16	32.6	......	......	......	......	36.0	+3.4	......	......	......	......	......	......	44.0	+11.4
17	37.7	......	......	......	......	40.9	+3.2	......	......	......	......	......	......	46.0	+8.3
18	35.1	......	......	......	......	42.1	+7.0	......	......	......	......	......	......	45.2	+10.1
19	33.0	......	......	......	......	38.3	+5.3	......	......	......	......	......	......	45.3	+12.3
20	37.1	39.6	+2.5	......	......	42.5	+5.4	......	......	......	......	......	......	48.3	+11.2
21	38.0	40.1	+2.1	41.7	+3.7	42.4	+4.4	44.0	+6.0	45.7	+7.7	47.1	+9.1	49.3	+11.3
23	34.1	36.1	+2.0	38.0	+3.9	39.5	+5.4	42.0	+7.9	43.1	+9.0	45.0	+10.9	45.0	+10.9
24	41.0	43.2	+2.2	44.9	+3.9	46.0	+5.0	47.4	+6.4	49.0	+8.0	50.7	+9.7	52.1	+11.1
25	41.0	44.2	+3.2	45.1	+4.1	46.0	+5.0	47.0	+6.0	48.7	+7.7	50.0	+9.0	52.0	+11.0
26	38.7	40.2	+1.5	42.7	+4.0	44.0	+5.3	46.0	+7.3	48.0	+9.3	49.2	+10.5	51.6	+12.9
27	35.1	37.1	+2.0	39.0	+3.9	40.7	+5.6	43.0	+7.9	44.1	+9.0	45.0	+9.9	47.0	+11.9
28	41.4	43.6	+2.2	45.4	+4.0	47.0	+5.6	49.8	+8.4	51.0	+9.6	52.1	+10.7	54.9	+13.5
29	38.1	40.3	+2.2	42.0	+3.9	42.8	+4.7	44.0	+5.9	45.3	+7.2	47.0	+8.9	49.0	+10.9
30	32.0	35.1	+3.1	38.0	+6.0	40.0	+8.0	41.4	+9.4	43.0	+11.0	44.0	+12.0	45.0	+13.0
31	29.9	31.8	+1.9	34.0	+4.1	37.0	+7.1	39.0	+9.1	40.0	+10.1	40.3	+10.4	41.0	+11.1
1920.															
Jan. 6	30.0	31.0	+1.0	31.7	+1.7	32.0	+2.0	33.0	+3.0	33.9	+3.9	34.9	+1.9	35.7	+5.7
7	27.5	28.8	+1.3	29.1	+1.6	29.9	+2.4	30.5	+3.0	31.0	+3.5	31.7	+4.2	32.0	+7.2
8	26.0	28.0	+2.0	29.9	+3.9	31.7	+5.7	33.0	+7.0	34.0	+8.0	35.0	+9.0	35.1	+9.1
9	26.1	28.0	+1.9	29.6	+3.5	31.0	+4.9	32.9	+6.8	34.5	+8.4	35.1	+9.0	36.0	+9.9
10	30.2	32.0	+1.8	33.0	+2.8	34.0	+3.8	35.1	+4.9	36.6	+6.4	37.8	+7.6	38.9	+8.7
13	30.1	31.9	+1.8	32.8	+2.7	33.7	+3.6	35.0	+4.9	35.6	+5.5	36.4	+6.3	37.1	+7.0
14	32.0	34.0	+2.0	36.8	+4.8	37.6	+5.6	38.7	+6.7	39.6	+7.6	40.7	+8.7	42.0	+10.0
15	29.0	30.9	+1.9	33.0	+4.0	34.0	+5.0	36.0	+7.0	37.0	+8.0	37.0	+8.0	37.4	+8.4
18	39.0	41.0	+2.0	42.0	+3.0	44.0	+5.0	46.1	+7.1	49.6	+10.6	51.0	+12.0	54.0	+15.0
25	38.1	39.3	+1.2	40.1	+2.0	41.0	+2.9	42.6	+4.5	44.9	+6.8	46.0	+7.9	49.1	+11.0
29	34.7	36.0	+1.3	37.6	+2.9	39.6	+4.9	42.8	+8.1	45.0	+10.3	45.0	+10.3	45.1	+10.4
Feb. 5	39.1	40.9	+1.8	42.0	+2.9	42.6	+3.5	43.4	+4.3	44.0	+4.9	44.5	+5.4	46.0	+6.9
6	37.7	40.0	+2.3	42.0	+4.3	42.7	+5.0	43.9	+6.2	45.6	+7.9	46.0	+8.3	47.1	+9.4
7	41.1	42.7	+1.6	43.4	+2.3	44.1	+3.0	46.3	+5.2	48.0	+6.9	49.1	+8.0	50.2	+9.1
11	33.5	34.4	+0.9	35.6	+2.1	35.6	+2.1	36.0	+2.5	36.4	+2.9	36.8	+3.3	37.0	+3.5
14	31.1	32.2	+1.1	33.4	+2.3	33.6	+2.5	34.3	+3.2	35.0	+3.9	36.0	+4.9	36.9	+5.8
15	34.6	35.8	+1.2	37.2	+2.6	38.0	+3.4	38.9	+4.3	39.9	+5.3	40.7	+6.1	41.4	+6.8
Average	33.9	35.3	+1.4	36.7	+2.8	37.5	+3.6	39.0	+5.1	40.2	+6.3	41.0	+7.1	42.3	+8.4

TABLE 8.—*Minimum temperatures on clear nights on 35-foot tower in pear orchard, Medford, Oreg.*

Date.	Elevation above ground.						
	5 feet.	15 feet.		25 feet.		35 feet.	
1919.							
Apr. 11	27.3	28.2	+0.9	29.8	+2.5	29.0	+1.7
12	29.9	30.9	+1.0	31.1	+1.2	31.0	+1.1
14	25.1	26.2	+1.1	27.9	+2.8	28.0	+2.9
20	29.4	30.6	+1.2	32.0	+2.6	31.7	+2.3
22	30.9	31.9	+1.0	33.2	+2.3	33.9	+3.0
26	29.2	30.9	+1.7	31.1	+1.9	32.0	+2.8
28	34.4	36.7	+2.3	37.4	+3.0	38.1	+3.7
29	34.0	36.9	+2.9	38.0	+4.0	39.0	+5.0
30	38.0	40.1	+2.1	42.0	+4.0	42.9	+4.9
May 1	32.6	34.2	+1.6	36.2	+3.6	38.0	+5.4
3	29.9	32.5	+2.6	33.5	+3.6	34.3	+4.4
4	28.0	30.1	+2.1	31.8	+3.8	33.0	+5.0
5	26.8	29.3	+2.5	31.8	+5.0	33.6	+6.8
6	30.6	32.8	+2.2	34.6	+4.0	36.7	+6.1
7	31.0	33.0	+2.0	35.0	+4.0	37.0	+6.0
10	28.0	29.9	+1.9	31.0	+3.0	31.1	+3.1
1920.							
Apr. 11	30.0	31.3	+1.3	32.5	+2.5	32.7	+2.7
18	25.0	27.2	+2.2	29.0	+4.0	28.6	+3.6
1920.							
Apr. 22	27.6	29.0	+1.4	29.7	+2.1	29.7	+2.1
23	24.4	26.8	+2.4	27.8	+3.4	27.4	+3.0
24	26.5	28.6	+2.1	30.6	+4.1	30.3	+3.8
25	29.0	30.8	+1.8	32.7	+3.7	32.3	+3.3
26	32.2	34.9	+2.7	37.0	+4.8	37.8	+5.6
27	31.9	34.0	+2.1	37.2	+5.3	38.0	+6.1
28	32.1	34.1	+2.0	36.4	+4.3	37.0	+4.9
29	28.3	30.0	+1.7	33.0	+4.7	34.5	+6.2
May 2	29.0	30.0	+1.0	31.6	+2.6	32.3	+3.3
3	26.9	28.9	+2.0	31.0	+4.1	31.1	+4.2
4	27.0	29.0	+2.0	30.3	+3.3	31.0	+4.0
5	31.6	34.0	+2.4	35.9	+4.3	36.3	+4.7
6	32.7	35.1	+2.4	36.8	+4.1	37.2	+4.5
7	36.9	39.1	+2.2	42.1	+5.2	43.7	+6.8
8	37.1	39.7	+2.6	41.5	+4.4	42.6	+5.5
10	29.7	31.0	+1.3	32.6	+2.9	33.0	+3.3
11	31.0	32.6	+1.6	34.1	+3.1	34.9	+3.9
14	30.1	32.9	+2.8	34.5	+4.4	35.0	+4.9
Average	30.1	32.0	+1.9	33.7	+3.6	34.3	+4.2